

1210.
OFFICE
~~DEP~~

NATIONAL BUREAU OF STANDARDS REPORT

6403

CAPACITY TESTS OF GENERAL ELECTRIC HEAT PUMP
MODEL 21 WT33G1

by

J. C. Davis, W. M. Ellis and P. R. Achenbach

Report to

Housing Construction Division
Directorate of Installations
United States Air Force
Washington, D. C.



U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

THE NATIONAL BUREAU OF STANDARDS

Functions and Activities

The functions of the National Bureau of Standards are set forth in the Act of Congress, March 3, 1901, as amended by Congress in Public Law 619, 1950. These include the development and maintenance of the national standards of measurement and the provision of means and methods for making measurements consistent with these standards; the determination of physical constants and properties of materials; the development of methods and instruments for testing materials, devices, and structures; advisory services to Government Agencies on scientific and technical problems; invention and development of devices to serve special needs of the Government; and the development of standard practices, codes, and specifications. The work includes basic and applied research, development, engineering, instrumentation, testing, evaluation, calibration services, and various consultation and information services. A major portion of the Bureau's work is performed for other Government Agencies, particularly the Department of Defense and the Atomic Energy Commission. The scope of activities is suggested by the listing of divisions and sections on the inside of the back cover.

Reports and Publications

The results of the Bureau's work take the form of either actual equipment and devices or published papers and reports. Reports are issued to the sponsoring agency of a particular project or program. Published papers appear either in the Bureau's own series of publications or in the journals of professional and scientific societies. The Bureau itself publishes three monthly periodicals, available from the Government Printing Office: The Journal of Research, which presents complete papers reporting technical investigations; the Technical News Bulletin, which presents summary and preliminary reports on work in progress; and Basic Radio Propagation Predictions, which provides data for determining the best frequencies to use for radio communications throughout the world. There are also five series of nonperiodical publications: The Applied Mathematics Series, Circulars, Handbooks, Building Materials and Structures Reports, and Miscellaneous Publications.

Information on the Bureau's publications can be found in NBS Circular 460, Publications of the National Bureau of Standards (\$1.25) and its Supplement (\$0.75), available from the Superintendent of Documents, Government Printing Office, Washington 25, D. C.

Inquiries regarding the Bureau's reports should be addressed to the Office of Technical Information, National Bureau of Standards, Washington 25, D. C.

NATIONAL BUREAU OF STANDARDS REPORT

NBS PROJECT
1000-30-4835

May 6, 1959

NBS REPORT
6403

CAPACITY TESTS OF GENERAL ELECTRIC HEAT PUMP
MODEL 21 WT33G1

by

J. C. Davis, W. M. Ellis and P. R. Achenbach
Air Conditioning, Heating, and Refrigeration Section
Building Technology Division

to

Housing Construction Division
Directorate of Installations
United States Air Force
Washington, D. C.
IMPORTANT NOTICE

NATIONAL BUREAU OF
intended for use within
to additional evaluation
listing of this Report, at
the Office of the Director
however, by the Government
to reproduce additional

Approved for public release by the
Director of the National Institute of
Standards and Technology (NIST)
on October 9, 2015.

or progress accounting documents
is formally published it is subjected
ting, reproduction, or open-literature
mission is obtained in writing from
C. Such permission is not needed,
ally prepared if that agency wishes



U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

CAPACITY TESTS OF GENERAL ELECTRIC HEAT PUMP
MODEL 21 WT33G1

by

J. C. Davis, W. M. Ellis and P. R. Achenbach

ABSTRACT

At the request of the Housing Construction Division, Directorate of Installations, United States Air Force, cooling and heating capacity tests were made of a General Electric Company heat pump, Model 21 WT33G1. The specimen was selected by Air Force representatives from among those furnished by the manufacturer for installation at Homestead Air Force Base, Florida. The indoor and outdoor conditions under which tests were to be made were agreed upon in a meeting of representatives of the U. S. Air Force, the General Electric Company, and the National Bureau of Standards. The tests, except for minor deviations, were made under the procedures and conditions specified in the American Society of Refrigerating Engineers Standard No. 16-56. The cooling capacity of the unit varied linearly from 35,400 Btu/hr to 31,100 Btu/hr for the range of outdoor temperature from 85°F to 105°F when the indoor conditions were maintained at 80°F dry bulb temperature and 67°F wet bulb temperature. Lowering the indoor dry bulb temperature to 75°F decreased the cooling capacity of the unit 2350 Btu/hr for the same range of outdoor temperatures. The heating capacity varied linearly from 38,400 Btu/hr to 24,600 Btu/hr for the range of outdoor temperature from 50°F to 20°F when the indoor dry bulb temperature was maintained at 70°F and the outdoor coil was kept free of frost. Under severe frosting conditions at an outdoor temperature of 35°F the average hourly heat output was reduced about 2900 Btu/hr or about 9.0 percent by the insulating effect of the frost on the outdoor coil and the interruption of heating during the defrosting period. The defrost cycle lasted from 3 to 4 1/2 minutes and was repeated every 35 or 40 minutes under the test conditions. The coefficient of performance varied linearly with outdoor temperature under both heating and cooling conditions. The coefficient of performance was 2.03 at an outdoor temperature of 35°F under heating conditions, and 1.75 at an outdoor temperature of 95°F under cooling conditions.

1. INTRODUCTION

In accordance with a request by letter of October 13, 1958, from Colonel Guy H. Goddard, Chief, Housing Construction Division, Directorate of Installations, Headquarters, United States Air Force, cooling and heating capacity tests were made of a General Electric heat pump, Model 21 WT33G1. The specimen tested was one of two chosen by Air Force representatives from units furnished for installation at the Homestead Air Force Base, Florida. Since the testing of this unit was not detailed in purchase specifications, the testing conditions were agreed upon in a meeting held on October 8, 1958, with the United States Air Force, the General Electric Company, and the National Bureau of Standards represented.

The following table summarizes the indoor and outdoor temperature and humidity conditions agreed upon for the tests. Carrying out the three cooling tests at an indoor temperature of 75°F was made contingent upon the cumulative cost of the tests. Actually, only two of these tests, at outdoor dry bulb temperatures of 105°F and 85°F, were performed. One heating test was to be made at an outdoor temperature of 35°F with some frost accumulation on the outdoor coil to determine the effect of the frost on the heating capacity and to permit an automatic defrosting cycle to occur during which the heating function would be interrupted. This test was to continue for at least 3 hours.

COOLING TESTS

<u>Indoor Conditions</u>			<u>Outdoor Temperature</u>
DB (°F)	WB (°F)	R.H. (%)	DB (°F)
80	67	-	85
80	67	-	95
80	67	-	105
78	65	-	91
75	-	50	85
75	-	50	95
75	-	50	105

HEATING TESTS

<u>Indoor Temp, DB</u> (°F)	<u>Outdoor Temp, DB</u> (°F)	<u>Special Conditions</u>
70	20	Outdoor coil, frost-free
70	35	" " " "
70	50	" " " "
70	35	Outdoor coil, frosted

One cooling test at an outdoor DB temperature of 95°F and indoor conditions of 80°F DB and 67°F WB was to be made with an external static resistance on the indoor blower of 0.30 in. W.G.; which was an intermediate value between that used by the General Electric Co. for testing and that anticipated in the Air Force houses. This test was then to be repeated with an external static resistance of 0.15 in. W.G. and all other cooling tests and the heating tests were to be made without further adjustment of the air dampers. The adjustments for static pressure were to be made with the compressor operating and the indoor coil condensing room moisture in the normal way. The heating tests were then to be performed without further adjustment of the air dampers. The air circulation rate of the indoor blower was not specified.

The vapor line and liquid line of the test unit were each to be approximately 25 ft long, with ten feet of the total being exposed to outdoor conditions.

The engineering data submitted to the U. S. Air Force by the General Electric Co. indicated that the capacity of the specimen would be as follows:

<u>Outdoor Temp. (°F)</u>	<u>Indoor Temp. (°F)</u>		<u>Capacity, (Btu/hr)</u>
	Cooling Conditions		
DB	DB	WB	
95	80	67	33,500
	Heating Conditions		
DB	DB	WB	
20	70	-	24,500
35	70	-	32,000
50	70	-	37,800

2. DESCRIPTION OF TEST SPECIMEN

The General Electric 21 WT33G1 heat pump is known as a "split type" or "remote type" heat pump in which one section of the apparatus is placed outdoors and the other inside the home at a suitable place for delivering conditioned air. These two sections were designated respectively on nameplates as 21 WTA40B11 and 21 WTB32E9, and will be referred to hereafter in the report as the outdoor unit and the indoor unit.

During the cooling cycle, the coil of the indoor unit served as an evaporator, absorbing heat; and during the heating cycle, as a condenser, rejecting heat. This operational change was accomplished by means of a change in direction of circulation of the refrigerant through the system, using thermostatically-controlled solenoids in a four-way valve. During the tests the solenoids were controlled by a manually-operated switch to preclude automatic shifting from cooling to heating conditions and vice versa. Thermostatic expansion valves were used as the liquid refrigerant flow control devices in both the indoor and outdoor units with check valves to bypass each when not needed. Following the new ASRE refrigerant designations, the refrigerant used was R-22.

A schematic diagram of the heat pump system and auxiliary test instrumentation is shown in Figure 1. A list of line sizes between the indoor and outdoor units is shown below. The liquid and vapor lines were each about 25 ft in length.

During the tests the vapor line was insulated with a glass fiber type material 1 in. thickness, vapor sealed.

1. Liquid line except for flowmeter manifold*, in. 3/8 OD
2. Lines in manifold*, in. 1/2 OD
3. Vapor line, in. 7/8 OD

* Part of testing apparatus.

GENERAL ELECTRIC HEAT PUMP

21 WT33G1

INDOOR UNIT

OUTDOOR UNIT

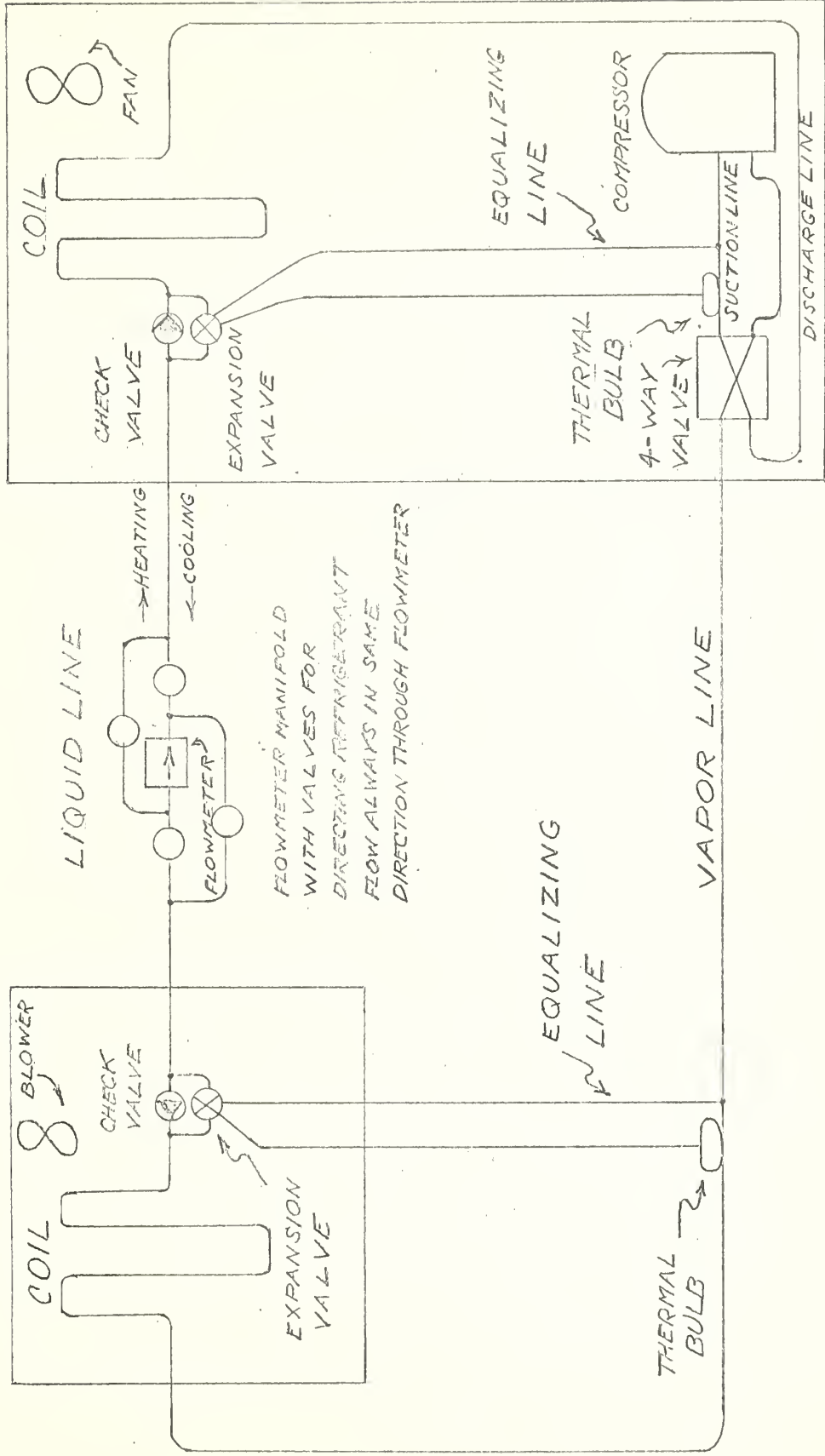


FIG 1

INDOOR UNIT

The indoor unit consisted essentially of a finned coil, a blower for circulating conditioned air through the duct system of the house, a motor for powering the blower, an expansion valve, a check valve, and a drain pan for collecting condensate. The indoor unit was designed for installation of resistance heaters to supplement compressor heating during extremes of cold weather. However, because of the mild weather usually prevailing at the Homestead Air Force Base, these heaters were not provided in these units. Material and dimensional data on the components of the indoor unit are contained in the Appendix at the end of the report.

Figure 2 shows the indoor unit ready for test inside the laboratory enclosure.

OUTDOOR UNIT

The outdoor unit consisted essentially of a finned coil, a blower, a hermetically-sealed motor-compressor, an expansion valve, a check valve, a four-way valve, a condensate drain, and 24-volt controls for operation and defrost. Material and dimensional data on the components of the outdoor unit are contained in the Appendix at the end of the report.

Figure 3 shows the outdoor unit with test equipment. Note the five-in-one thermocouple system and the thermostat used for controlling outdoor conditions during the test.

The heat pump system arrived from the manufacturer with a complete R-22 charge, contained principally in the outdoor unit. The amount of charge was selected to be adequate for installations employing moderate length liquid and vapor lines. The indoor unit held R-22 under pressure within its coils and refrigerant lines. Gas was released from the indoor unit when the lines between outdoor and indoor units were connected, thus indicating that the indoor lines were probably without leaks.

The controls on the outdoor unit consisted of a defrost control system employing a pressure-sensing device and a defrost termination switch, and a combination high and low pressure switch.



FIGURE 2 INDOOR UNIT IN TEST ENCLOSURE

27830 1

OFFICE FILE COPY

DIVISION _____ SECTION _____

PRINT FROM BUREAU OF STANDARDS
PHOTOGRAPHIC LABORATORY

ORDER DUPLICATION COPIES
BY NUMBER

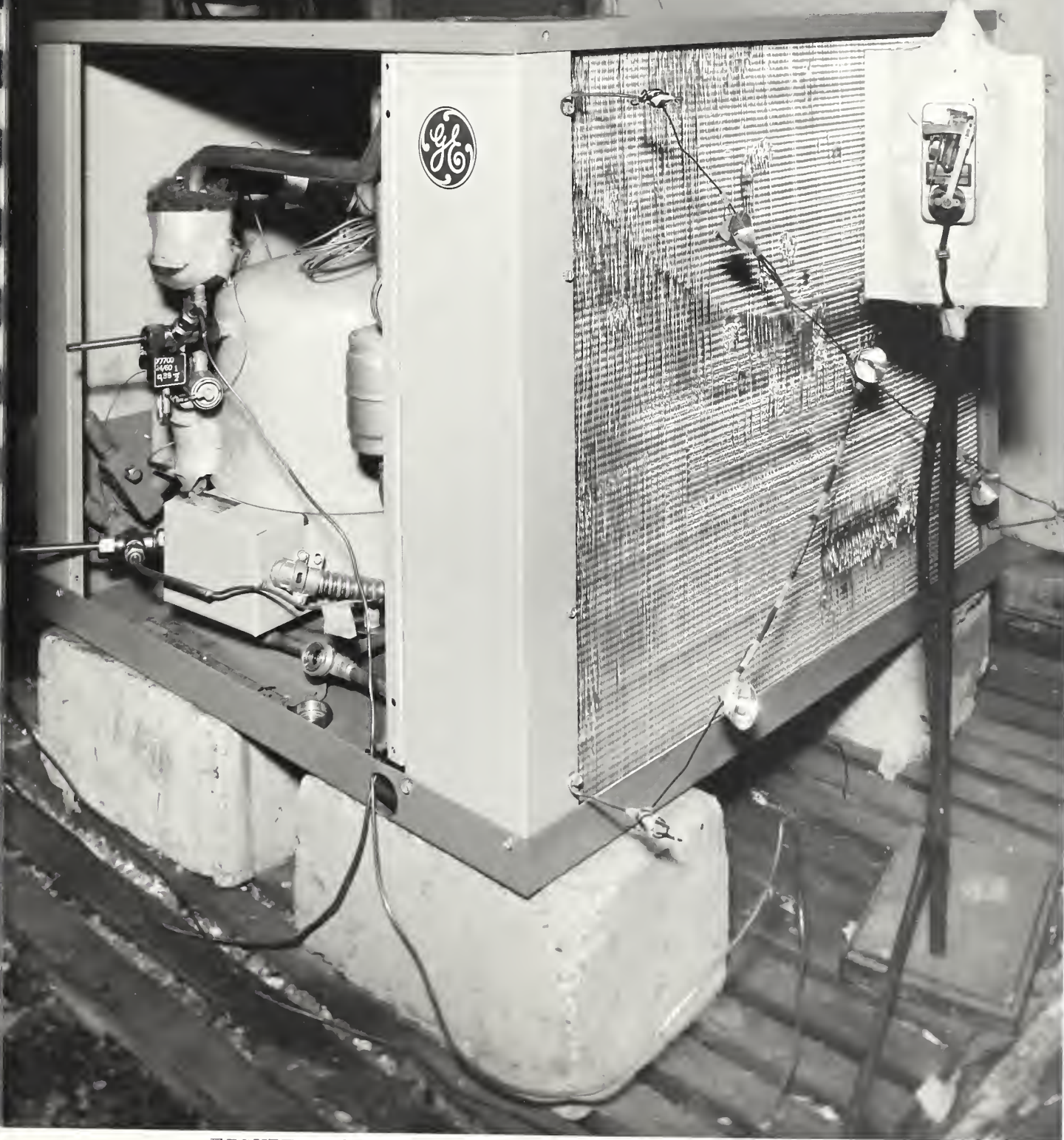


FIGURE 3 OUTDOOR UNIT WITH TEST EQUIPMENT

27830 2

Defrosting was initiated by a pressure-sensing device actuating the solenoid of the four-way valve to place the unit on cooling operation. Under these conditions the outdoor coil became a condenser and the frost was melted by the heat rejection in the condenser. The outdoor fan was stopped during the defrosting period. The pressure-sensing device employed a diaphragm, which was actuated by a threshold difference between atmospheric pressure and the pressure at the inlet to the outdoor fan. This pressure difference gradually increased as frost accumulated on the outdoor coil.

The defrost termination switch ended the defrost period when a sufficiently high temperature was reached in the outdoor coil to assure that no frost remained. When this switch opened, the four-way valve was switched from cooling to heating operation and the outdoor fan was energized again. Defrosting could not be initiated by the pressure-sensing device unless the defrost termination switch was closed, but this was its normal position during winter operation. During spring or summer operation the defrost termination switch was always open.

During the defrosting period, the suction pressure sometimes fell below the setting of the low-pressure cut-off switch. Stopping of the compressor was prevented, however, by means of an electrical shunt around the low-pressure switch that was closed when the defrost relay operated.

The high pressure switch stopped the unit when the discharge pressure was too high and the low-pressure switch stopped the unit when the suction pressure was too low. The high pressure switch was of the manual reset type and the low pressure switch of the automatic reset type.

3. METHODS OF TESTING

Except for minor deviations, the heat pump was tested under the conditions described in ASRE Testing and Rating Standard No. 16-56. Figure 4 shows the enclosure housing the indoor unit and the 33-in. square test duct attached to the outlet side of the unit. This duct housed the nozzle used for measuring the air circulation rate and the instruments for measuring

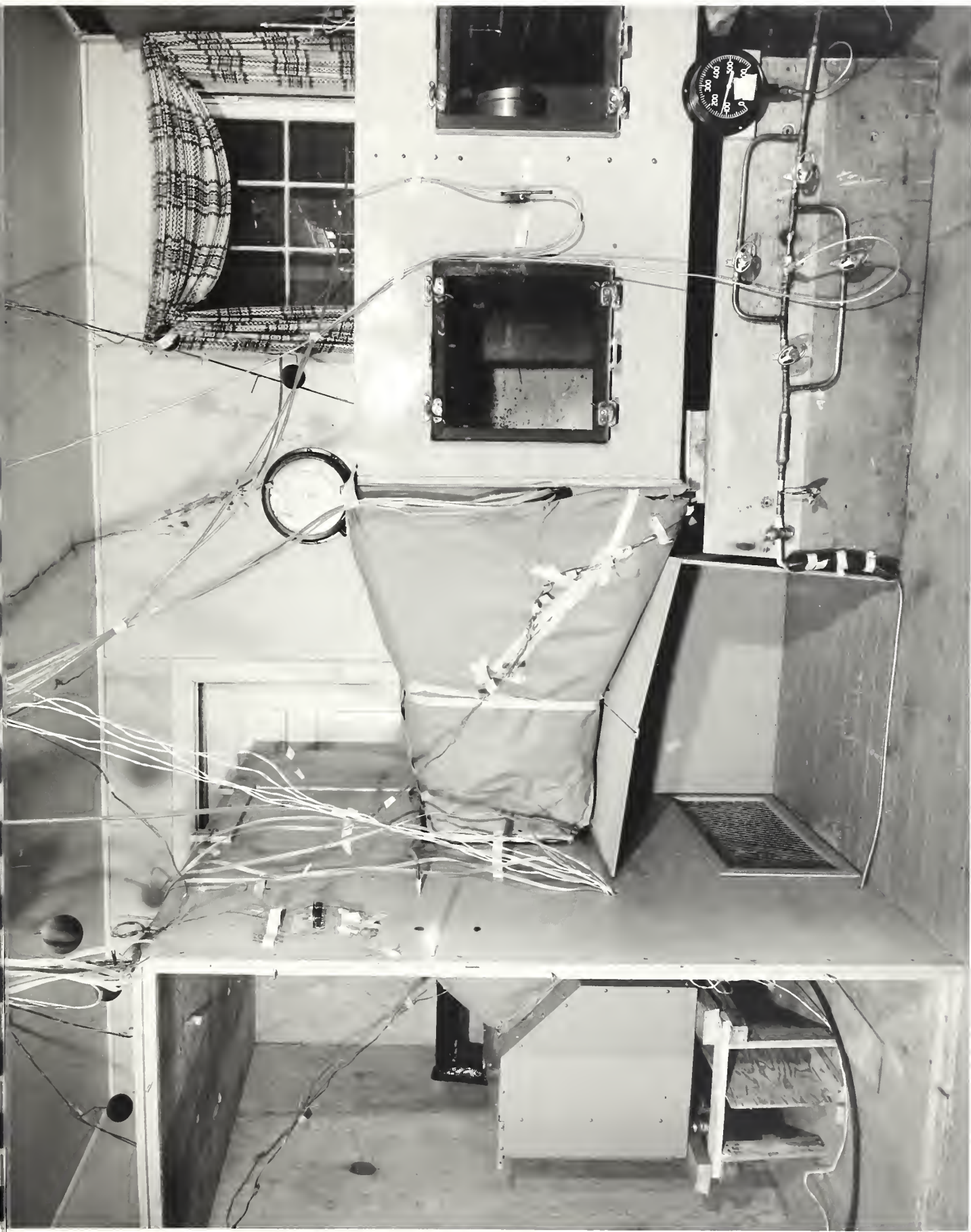


FIGURE 4 TEST ENCLOSURE; DUCT SYSTEM AND MANIFOLD

temperature and humidity of the outlet air. Because the nozzle, mixing baffles, and mixing screen introduced considerable resistance in the outlet duct, an auxiliary blower powered by a one HP motor was provided at the downstream end of the 33-in. duct. Required adjustments of external static resistance on the unit under test were made by a wooden slide-type damper at the outlet of the auxiliary blower. The air delivery rate of the indoor blower depended only on the adjustment of this damper, since the pulley on the blower was not adjustable. The auxiliary blower, return air heaters, and humidifier are shown in Figure 5.

ASRE Standard 16-56 requires that two independent measuring methods be used during the test to provide greater reliability in the results. One method, known as the psychrometric method, involved measuring the mass flow of air through the indoor unit and the change in enthalpy of the air between inlet and outlet of the unit. The other method, referred to as the flowmeter method, involved determination of the rate of flow of refrigerant through the indoor coil and the change in enthalpy of the refrigerant between inlet and outlet of the indoor coil. A correction to the total enthalpy change of the refrigerant was necessary, either by adding or subtracting the heat equivalent of the electrical energy supplied to the indoor blower motor depending on whether the heating or cooling cycle was in use, before comparing it with the result of the psychrometric method. Acceptable precision required that the values obtained by the two methods should not differ by more than six percent.

Mass flow rate of air in the psychrometric method was determined by measuring humidity and temperature conditions of the air entering the long-radius nozzle and the static pressure drop across the nozzle. Enthalpy change of the air was determined by measuring temperature, humidity, and barometric pressure of the air entering the indoor unit, and in the duct immediately after it left the unit.

Flow rate of refrigerant was measured by means of a flowmeter in the liquid line of the system - a Potter Electronic type with an impeller which generated an electrical pulse on

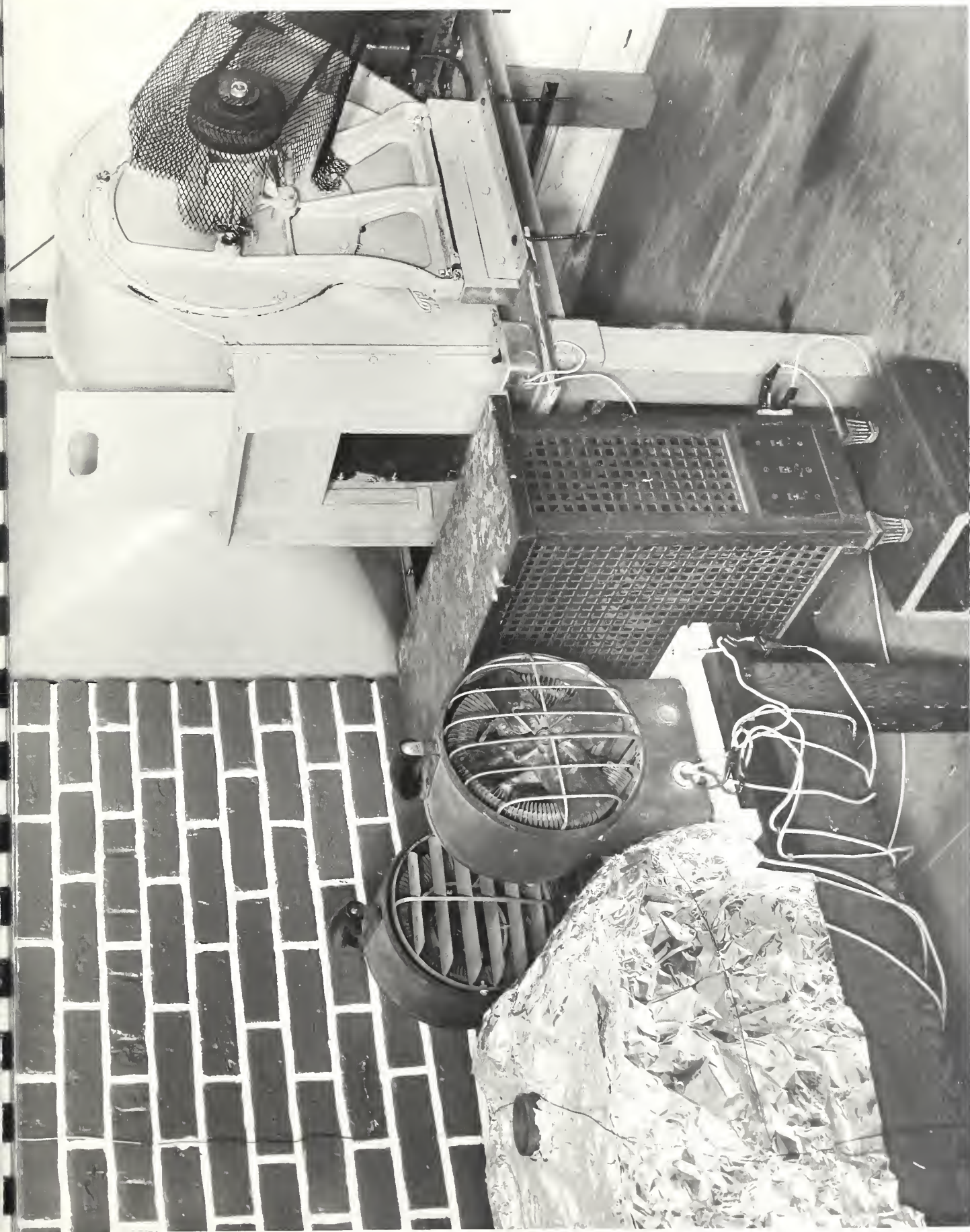


FIGURE 5 AUXILIARY BLOWER

27134 I

each revolution. A Potter Counter coupled to the flowmeter served to translate the pulses into a volume flow rate. By measuring the temperature of the liquid in the line, the volume flow rate was converted to mass flow rate. Enthalpy change was determined by temperature and pressure measurements at the inlet and outlet of the indoor coil. For accurate measurement of capacity by the refrigerant flow method it was necessary that there be no gas bubbles in the liquid refrigerant as it passed through the meter, and that the liquid refrigerant all be evaporated in the coil.

It was possible to maintain "state" conditions for both cooling and heating with the use of a test structure having two controlled temperatures.

During the tests, the energies consumed by the indoor blower, outdoor fan and compressor were read from separate watt-hour meters. Simultaneous readings were also made of currents and voltages. The various meters, together with the other instruments for measuring temperature and humidity, are shown in Figure 6.

The same amount of refrigerant charge was used for the cooling tests as for the heating tests. By agreement with the General Electric Co. representative, a run on the cooling cycle at an outdoor temperature of 95°F DB and indoor conditions of 80°F DB and 67°F WB was made at the beginning of the test program with a trial charge. An amount of refrigerant somewhat greater than the factory charge was necessary because of the volume of the gage lines and other lines not found in home installations. After adjusting the charge to obtain the correct pressures and temperatures, operation was switched to heating at 20°F outdoor temperature. Since pressures and temperatures appeared normal under these conditions, the charge was left unchanged for all tests under both heating and cooling conditions. It is of interest to note that specifications at the General Electric plant call for storage of about 8 lbs of refrigerant in the outdoor unit; whereas on completion of the tests, measurements showed that the test charge was very close to 9 lbs. The indications were that no refrigerant leakage occurred during the tests.

Before each test run, steady-state conditions were held for a minimum of one hour. During all runs, readings were taken every ten minutes. In most cases the data for an hour

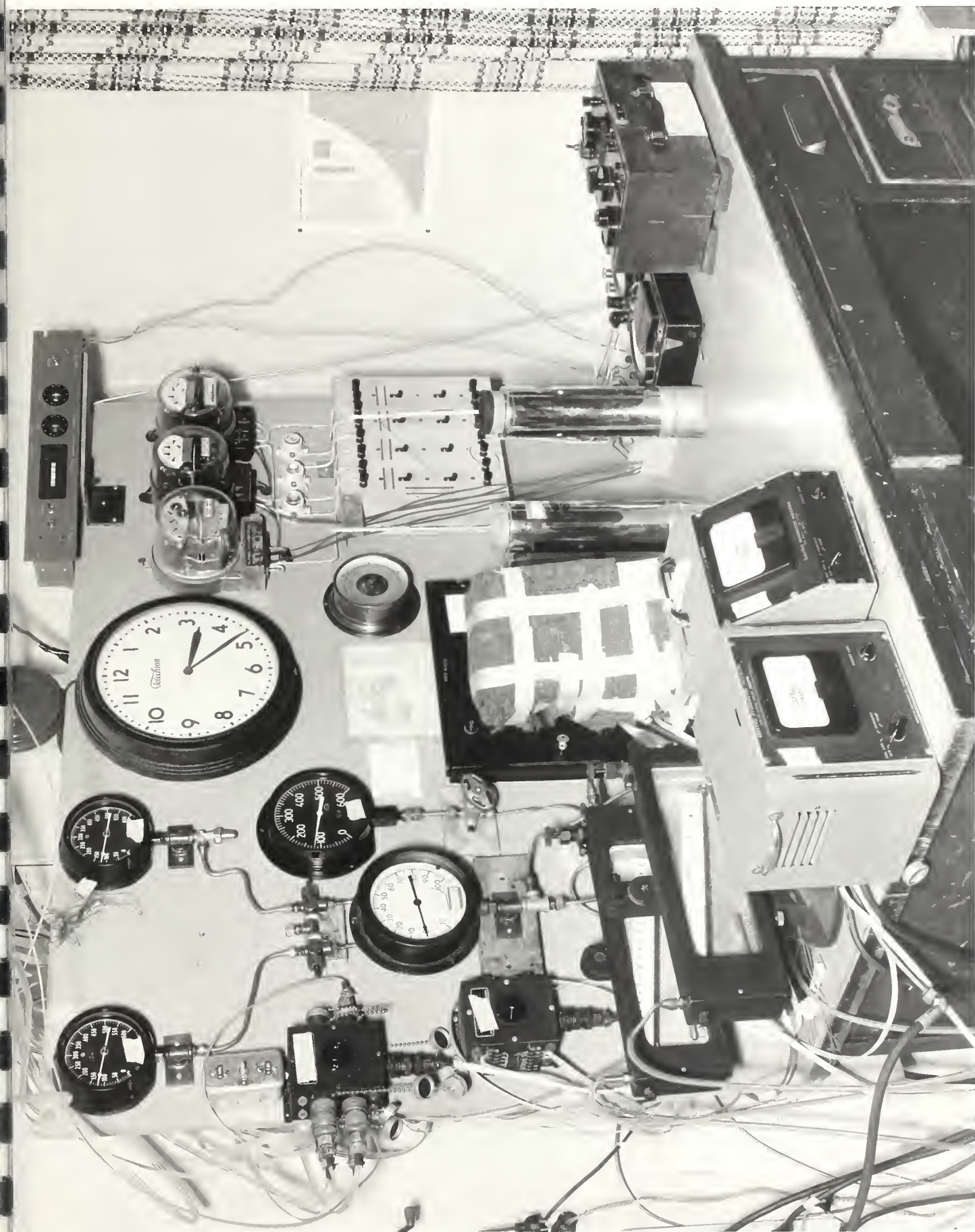


FIGURE 6 TEST PANEL

27184 5

representing the steadiest conditions were used for evaluating performance.

During the heating test at an outdoor temperature of 20°F, the pressure drop across the liquid flowmeter was excessive and the flow rate varied in a cyclic manner. For these reasons, the flowmeter data were not used in evaluating this test.

The special test with the coil of the outdoor unit operating under frosting conditions was performed at 35°F with a wind-blown mist directed toward the coil face. Before starting the test, the controls of the unit were arranged so the heat pump would defrost automatically in the normal sequence determined by its defrost controls.

During the morning of the test, fine spray was blown towards the outdoor coil and the rate was adjusted until the defrost cycle occurred once in about 35 to 40 min. During the test, readings were made every ten minutes, as was done for all other tests. When defrost cycles occurred during the periods between readings, the most pertinent pressures, temperatures, and electrical values were read about 2 1/2 minutes after defrost initiation, and when the gages appeared to have become steady under cooling cycle operation. Each defrost cycle lasted from 3 to 4 1/2 minutes. The entire test lasted for 3 hours and all data were used in the calculations.

As a first step in the calculations, capacity was determined in Btu/hr as if no defrost cycles had occurred. As would be expected, calculations showed that capacity decreased as frosting increased during each period between defrosts. As a second step, the heating effect that was lost during the defrosting periods was calculated and subtracted from the values first obtained. Certain approximations were necessary in calculation of this last step because of the difficulty in taking accurate readings during the periods of rapidly changing conditions.

Because of these large and abrupt changes in the refrigerant flow in the system, it was impossible to use the flowmeter during this test.

4. TEST RESULTS

A. Table 1 summarizes the results obtained on cooling capacity, heating capacity, and coefficient of performance for the various test conditions agreed upon. These data are plotted separately for the cooling tests and heating tests in Fig. 7 and 8, respectively. These figures show that both the coefficient of performance and the capacity of the heat pump was very nearly linear with respect to outdoor temperature when the indoor conditions were held constant.

Fig. 7 shows that the cooling capacity of the test specimen was reduced an average of 2350 Btu/hr by lowering the indoor dry bulb temperature from 80°F to 75°F and keeping the relative humidity constant. This difference was constant for the range of outdoor temperature from 85°F to 105°F. The change in indoor dry bulb temperature also changed the coefficient of performance by a constant amount throughout this same range of outdoor temperature.

The data in Table 1 show that the static pressure difference between the outlet of the indoor unit and the unit inlet averaged about 0.18 in. W.G. during the heating tests, which were performed first. This was the static pressure created in the system during the heating tests without readjustment of dampers, after initially adjusting the static pressure to 0.15 in. W.G. during cooling conditions.

It was noted as the cooling tests progressed that the static pressure at the unit outlet gradually decreased to values as low as 0.05 and 0.06 in. W.G. This effect was caused by dust deposits on the air filter located in the unit inlet. Changing the filter restored the outlet static pressure to 0.15 in. W.G. A comparison of the three cooling tests in Table 1 at an outdoor temperature of 95°F indicates that static pressure variations in the range from 0.05 to 0.30 in. W.G. caused less than 2 percent change in cooling capacity which is probably less than the precision of this type of test. Air flow rate, however, was reduced by nearly 10% as static pressure changed from 0.15 in. W.G. to 0.30 in. W.G. The air filter was clean for both of these tests.

The variations in static pressure at the unit outlet cannot be correlated satisfactorily with the variations in air delivery because two blowers were connected in series in the test apparatus for these tests.

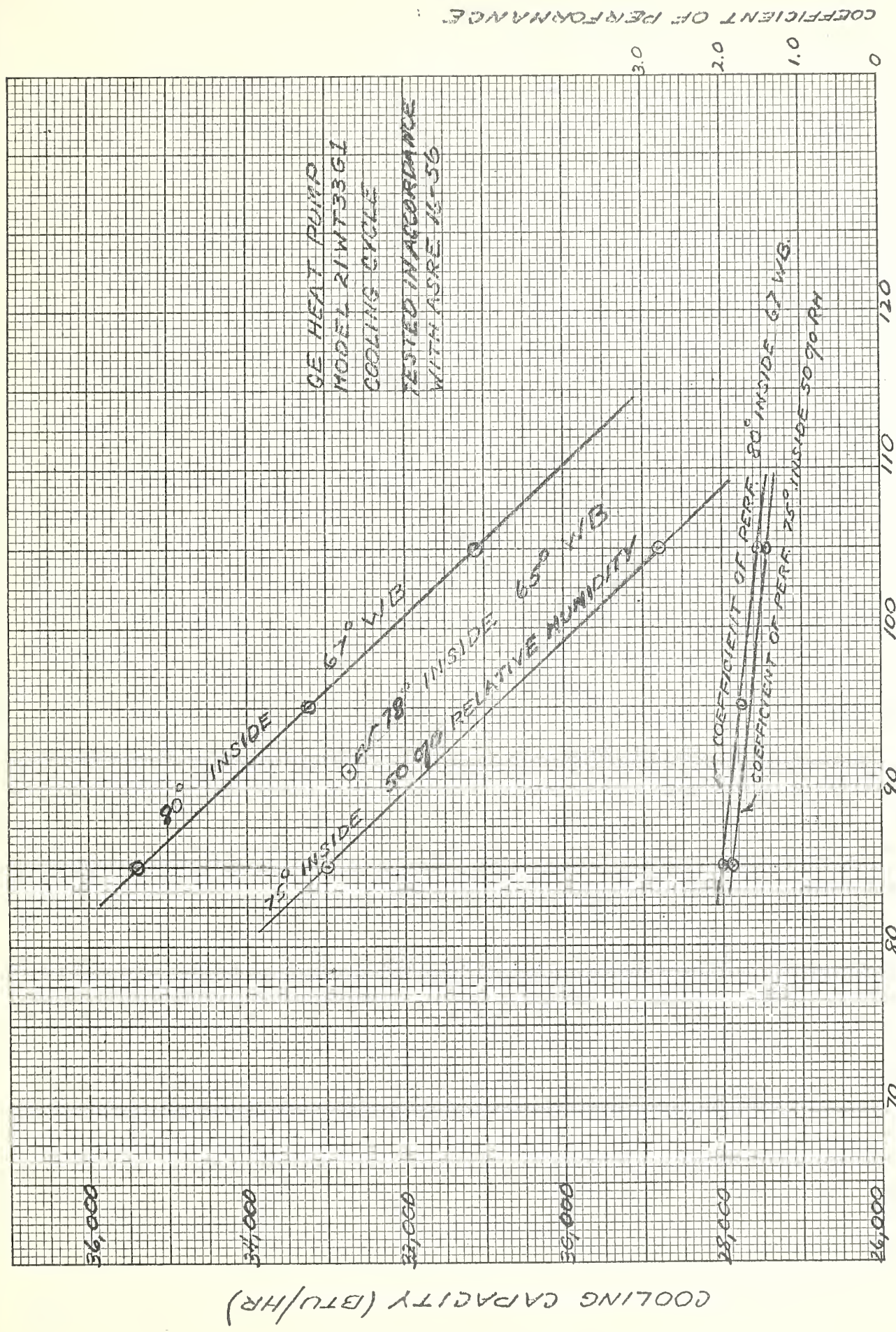


FIG. 7 OUTDOOR TEMPERATURE (°F)

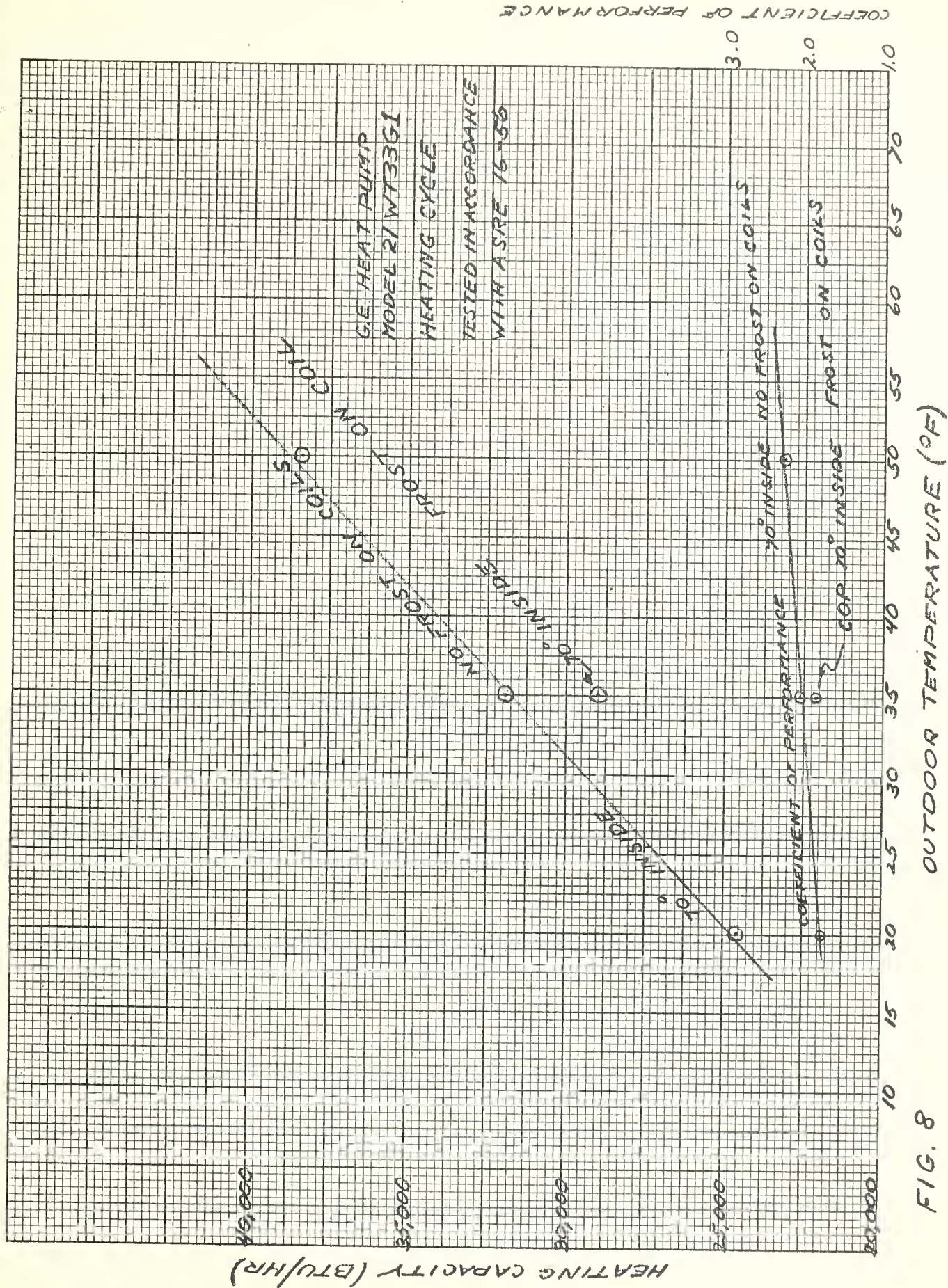


Table 1

RESULTS OF TESTS

COOLING CONDITIONS

Test Conditions		Stat. Res. at Outlet of Indoor Unit	Air Delivered by Blower	Psychrometric Capacity	Flowmeter Capacity	Allowance for Deviation of Bar. Press.	Corrected Average Value	C.O.P.
Inside DB	WB or Humidity (°F or %)							
Outdoors		(in. W.G.)	(cfm)	(Btu/hr)	(Btu/hr)	(Btu/hr)	(Btu/hr)	(Btu/hr)
DB	(°F)							
80	67	0.30	1110	32,570	32,870	-	32,700	1.73
80	67	.15	1215	33,520	32,970	-	33,200	1.73
80	67	.05	1140	33,690	32,350	50	33,100	1.75
78	65	.12	1210	32,860	32,400	80	32,700	1.77
80	67	.06	1145	35,850	34,600	190	35,400	1.97
80	67	.02	1140	31,430	30,610	50	31,100	1.35
75	50%	.15	1215	34,100	31,990	-	33,000	1.88
75	50%	.15	1220	29,200	28,490	-	28,800	1.47

HEATING CONDITIONS

70	20	.19	1195	24,440	-	110	24,600	1.74
	(No frost)							
70	35	.18	1195	32,740	30,580	190	31,900	2.03
	(No frost)							
70	50	.16	1190	38,730	37,180	400	38,400	2.23
	(No frost)							
70	35	.18	1230	-	-	400	29,000	1.87
	(Frost)*							

* See discussion following on this test

B. Cooling Test Under Standard ASRE Conditions

Details of a typical cooling test with the outdoor temperature at 95°F, the indoor temperature at 80°F DB, and with 67°F WB are given below. Static resistance at the outlet of the indoor blower was 0.15 in. W.G. for this test.

Summary of Cooling Capacity Values (Btu/hr)

	<u>Test Value</u>	<u>Rounded Value</u>
By psychrometric method	33,520	
By flowmeter method	<u>32,970</u>	
Average	33,245	
Allowance for deviation of barometric pressure from normal	0.0	
Total	<u>33,245</u>	33,200

Psychrometric Method

Air Temperatures (°F)

At inlet to enclosure around indoor unit	79.9
At outlet of indoor unit in duct	<u>60.5</u>
Temperature difference across indoor coil	19.4
At inlet to outdoor unit	95.0

Wet Bulb Depressions

At inlet to enclosure around indoor unit	13.0
At outlet of indoor unit in duct	2.5
<u>Static pressure across nozzle (in. W.G.)</u>	1.35

<u>Volume air flow at nozzle (cfm)</u>	1215
<u>Mass air flow at nozzle (lb dry air/hr)</u>	5480
<u>Barometric pressure (in. Hg)</u>	29.94
<u>Area of nozzle (sq ft)</u>	0.268
<u>Nozzle coefficient</u>	0.981
<u>Static resistance external to unit (in. W.G.)</u>	0.15

Flowmeter Method

Refrigerant Temperatures (°F)

In vapor line leaving coil of indoor unit	49.7
In liquid line entering coil of indoor unit	111.4
Superheat at indoor coil outlet	5.0
Subcooling at indoor coil inlet*	9.2
In discharge line of compressor	233.0
In suction line of compressor	63.4

* Subcooling determined using pressure at point of measurement

Refrigerant Pressures (psig)**

Compressor discharge	290
In liquid line preceding flowmeter	278.5
In liquid line entering coil of indoor unit	271
Pressure drop across flowmeter	7.5
In vapor line leaving coil of indoor unit	76
In suction line of compressor	70.5

** Pressure referenced to compressor level

<u>Potter meter count for 1 minute</u>	32.7***
--	---------

Motor power consumption (Watts)

Indoor blower	460
Outdoor fan	540
Compressor	4620
Total	5620

*** Refrigerant flow, gal./min = $\frac{\text{count for one minute} \times 100}{3365.5}$

<u>Coefficient of performance</u>	1.73
-----------------------------------	------

<u>Motor voltages (Volts)</u>	
-------------------------------	--

Indoor blower	115.5
Outdoor fan	230.0
Compressor	230.0

<u>Motor current (Amperes)</u>	
--------------------------------	--

Indoor blower	4.9
Outdoor fan	2.6
Compressor	20.5

C. Heating Test at 20°F Outdoor Temperature

Details of the heating test with the outdoor temperature at 20°F and the indoor temperature at 70°F are given below:

Summary of Heating Capacity Values (Btu/hr)

	<u>Test Value</u>	<u>Rounded Value</u>
By psychrometric method	24,440	
Allowance for deviation of barometric pressure from normal	<u>110</u>	
Total	24,550	24,600

Psychrometric Method

<u>Air Temperatures (°F)</u>	
------------------------------	--

At inlet to indoor unit	70.0
At outlet of indoor unit in duct	89.8
Temperature difference across indoor coil	19.8
At inlet to outdoor coil	20.6

<u>Relative humidity of indoor air in duct (%)</u>	12.7
<u>Static pressure across nozzle (in. W.G.)</u>	1.23
<u>Volume air flow at nozzle (cfm)</u>	1195
<u>Mass air flow at nozzle (lb dry air/hr)</u>	5095
<u>Barometric pressure (in. Hg)</u>	29.69
<u>Area of nozzle (sq ft)</u>	.268
<u>Nozzle coefficient</u>	.981
<u>Static pressure at indoor blower outlet (in. W.G.)</u>	.19
<u>Refrigerant Pressures (psig)*</u>	
Compressor discharge	229.5
In vapor line entering coil of indoor unit	227.0
In liquid line leaving coil of indoor unit	225.5
In liquid line after flowmeter	217.0
Pressure drop across flowmeter	8.5
Suction pressure at compressor	27.0

* Referenced to compressor level

Other Temperatures

Compressor discharge	217.8
Near 4-way valve between valve and indoor unit	195.3
At inlet to coil of indoor unit	191.4
At outlet to coil of indoor unit	76.5
Suction line at compressor	18.9
Superheating at compressor	107.0**
Superheating at inlet to coil of indoor unit	82.6**
Subcooling at outlet to indoor unit	32.0**
Superheating at suction line of compressor	15.5**

** Subcooling or superheating determined using pressure at point of measurement

Motor power consumption (Watts)

Indoor blower	411.5
Outdoor fan	650.5
Compressor	<u>3072.5</u>

Total 4134.5

<u>Coefficient of performance</u>	1.74
-----------------------------------	------

Motor voltages

Indoor blower	115.0
Outdoor fan	230.0
Compressor	230.0

Motor current (Amperes)

Indoor blower	4.5
Outdoor fan	3.1
Compressor	14.3

D. Heating Test with Frosted Coil

A summary of the capacity values for the heating test with frosted outdoor coil is shown below. The outdoor temperature was 35°F.

Heating Capacity Values (Btu/hr)

	<u>Test Value</u>	<u>Rounded Value</u>
By psychrometric method	31,960	
By flowmeter method (estimated*)	29,820	
Average of two methods	30,890	
Loss in capacity during defrost cycles	2,310	
Net value	28,580	
Allowance for deviation of barometric pressure from normal	<u>400</u>	
	28,980	29,000

* Estimate based on ratio of psychrometric value of flowmeter values for heating test at 35°F outdoors without frost.

E. Motor Currents vs. Nominal Ratings

The current used during the tests by the motors on the indoor blower and outdoor fan was within that allowed by the National Electric Manufacturers Association Standards, or 1.35 service factor times the nominal rating. Nominal ratings, allowable maximum current, and the maximum readings observed during the tests are summarized below:

	<u>Nominal Ratings</u> (amperes)	<u>Allowable Maximum Current</u> (amperes)	<u>Maximum Current Reading</u> (amperes)
Indoor blower	4.30	5.80	4.95
Outdoor fan	2.35	3.17	3.00

Values as low as 2.50 amperes were obtained for the outdoor fan on the cooling tests and 4.43 amperes for the indoor blower on the heating tests.

Information on the nominal current rating of the compressor motor was not readily available.

F. Temperature drop across 4-way valve, heating test

During heating tests on other heat pumps at 20°F outdoor temperature, the temperature drop between the compressor and inlet to the indoor coil was greater than 30°F. In all cases the vapor line was well insulated where it was surrounded by the cold outdoor temperature. This decrease in temperature seemed rather large but there was insufficient instrumentation used during testing to make a complete analysis of the causes.

During the test on the Model 21 WT33G1 General Electric Company heat pump extra thermocouples were placed in the outdoor unit, one of which was positioned on the vapor line between the 4-way valve and the indoor unit. In this way it was possible to isolate data for the temperature drop due to heat exchange in the 4-way valve.

Inspection of the listing of refrigerant temperatures for the 20°F heating test, Part C of the Test Results, will show that the temperature decreased from the compressor discharge to the inlet of the coil in the indoor unit about 26°F, and that 22°F of this decrease occurred across the 4-way valve. A rather high value like this would be expected considering the large difference in temperature of 199°F between the discharge gas and the suction gas entering the 4-way valve. Temperatures measured during the 35°F and 50°F heating tests showed temperature drops in each case of about 20°F between compressor discharge and indoor unit, with about 10°F drop across the 4-way valve.

G. Calculation of oil in content in refrigerant

To determine the amount of oil flowing through the lines with the refrigerant and the effect of this oil on the flow-meter registration, the refrigerant was sampled under both cooling and heating conditions. The refrigerant, taken from the line while the heat pump was operating, was discharged into special flasks precooled by dry ice, and then allowed to evaporate slowly as the ice melted, leaving a residue of oil. The ratio of oil to refrigerant was measured volumetrically. This method was checked by a gravimetric method in which the refrigerant was withdrawn from the heat pump liquid line into an evacuated copper vessel at room temperature, and the residue of oil weighed after the refrigerant had slowly evaporated for comparison with the weight of refrigerant and oil. The ratio of oil to refrigerant was about 0.01 by weight for both cooling and heating conditions, and agreed reasonably well with the volumetric determinations.

APPENDIX

A. Material and Dimensional Data on Components of Indoor Unit

Coil

Three rows of 3/8 in. OD copper tubing, 20 tubes each row 1 in. apart, center to center. 14 aluminum fins per inch of tube length. Dimension of coil assembly: 20 in. high, 25 in. wide, 4 1/2 in. deep.

Blower

Centrifugal; direct driven; wheel, 9 1/2 in. wide, 10 in. diameter; scroll, 12 in. wide, 14 1/2 in. diameter.

Blower Motor

General Electric AC 1/6 HP, 1075 rpm. Model 5KCP3966609T. Thermal protection. GE J3308, 50°C rise. cont. air over motor. Ser. VRD-2, 4.3 amps. 115 volts, 60 cycles. Requires oiling.

Expansion Valve

Alco, non-adjustable, thermostatic type, 3/8 in. OD sweat, 237 HG. Charged thermal bulb. External equalizer, 1/4 in. OD line.

Check Valve

One-half in. sweat, pressure-activated.

Air Filter

One glass fiber filter, throw-away type, 20 in. wide, 20 in. high, 1 in. thick.

Insulation of Cabinet

One in. of glass fiber covered with moisture-resistant paper.

Description of Lines Inside Indoor Unit

Liquid line $3/8$ in. OD. Vapor line $5/8$ in. OD and $7/8$ in. OD. Header line $5/8$ in. OD. Four $1/4$ in. distributor lines to coil. All lines brazed with "Sil-Fos"-type solder.

Housing Dimension, Indoor Unit

21 in. high, $22\ 1/2$ in. wide, $22\ 1/2$ in. deep, Duct opening, $10\ 1/2$ in. by $11\ 3/4$ in. Wall thickness .048 in.

Nameplate, Indoor Unit

Model 21 WTB32E9. Motor $1/6$ HP, 3.6 F.L. amps, 1 phase, 60 cycles, 115 volts. Test pressure 420 psi, Refrigerant-22, Ser. No. 2002900.

B. Material and Dimensional Data on Components of Outdoor Unit

Coil

Three rows of $1/2$ in. OD copper tubing, 20 tubes each row, $1\ 1/4$ in. apart, center to center. Twelve aluminum fins per in. of tube length. Dimension of coil assembly: 25 in. high, $28\ 1/2$ in. wide, $3\ 1/4$ in. deep.

Fan

Propeller "pull through" type, direct driven, 20 in. diameter, for $1/2$ in. shaft. 5 blades, metal, approximately 40° pitch.

Fan Motor

General Electric $1/3$ HP, 1075 rpm. Model 5KCP37MG1351, 230 volts, 2.35 amps, 60 cycles, 1 phase, thermal protection, 50°C rise, cont. air over motor, $1/2$ in. shaft, Ser. No. WRD-2. Requires oiling, capacitor start.

Motor-Compressor Unit

General Electric, Refrigerant-22, Model 21CT 4HH41, 230 volts, 1 phase, 60 cycles, Serial No. 132873840, F.L. amps. 21.5, L.R. amps. 98, test pressure 350 psi. Rubber mounted. Hermetic sealed. Includes thermal overload and external locked rotor protector, both automatically reset.

Expansion Valve

Alco, non-adjustable, thermostatic type, 5/8 in. OD sweat, external equalizer, 1/4 in. line, charged thermal bulb.

Check Valve

Pressure-activated, 1/2 in. OD sweat.

Four-Way Valve

Alco, Solenoid-operated on low voltage 24 volts.

Other Components

Drier in liquid line 1/2 in. OD sweat, sight glass, 1/2 in. OD sweat.

Insulation in Housing

One inch of glass fiber, 9 in. by 31 1/2 in. under top cover to cover coil assembly only. No foil.

Description of Lines of Outdoor Unit

Discharge line from compressor to 4-way valve 1/2 in. OD. Suction line from compressor to 4-way valve, 7/8 in. OD. Line from 4-way valve to coil 7/8 in. OD. Vapor line inside of unit 7/8 in. OD. Liquid line inside of unit 1/2 in. OD. Three distributor lines from expansion valve to coil 1/4 in. OD. Header line 7/8 in. OD. All lines brazed with "Sil-Fos"-type of solder.

Housing, Outdoor Unit

25 1/2 in. high, 31 1/2 in. wide, 28 in. deep. Thickness,
.048 in.

Nameplate Covering Outdoor Unit

General Electric Weathertron Model 21 WTA40B11, Ser. No.
253321S40, Fan motor 1/3 HP, 2.35 amps, 230 volts, 1 phase,
60 cycles, compressor motor amps. 20.0, 230 volts, 1 phase,
60 cycles, L.R. amps. 96 Ref.-22, 8 lbs, high side test
420 psi, low side test 150 psi. Cat. No. 21D1011387,
Ser. No. 353321840.

U. S. DEPARTMENT OF COMMERCE

Lewia L. Strauss, *Secretary*

NATIONAL BUREAU OF STANDARDS

A. V. Asth, *Director*



THE NATIONAL BUREAU OF STANDARDS

The scope of activities of the National Bureau of Standards at its headquarters in Washington, D. C., and its major laboratories in Boulder, Colo., is suggested in the following listing of the divisions and sections engaged in technical work. In general, each section carries out specialized research, development, and engineering in the field indicated by its title. A brief description of the activities, and of the resultant publications, appears on the inside front cover.

WASHINGTON, D. C.

Electricity and Electronics. Resistance and Reactance. Electron Devices. Electrical Instruments. Magnetic Measurements. Dielectrics. Engineering Electronics. Electronic Instrumentation. Electrochemistry.

Optics and Metrology. Photometry and Colorimetry. Optical Instruments. Photographic Technology. Length. Engineering Metrology.

Heat. Temperature Physics. Thermodynamics. Cryogenic Physics. Rheology. Engine Fuels. Free Radicals Research.

Atomic and Radiation Physics. Spectroscopy. Radiometry. Mass Spectrometry. Solid State Physics. Electron Physics. Atomic Physics. Neutron Physics. Radiation Theory. Radioactivity. X-rays. High Energy Radiation. Nucleonic Instrumentation. Radiological Equipment.

Chemistry. Organic Coatings. Surface Chemistry. Organic Chemistry. Analytical Chemistry. Inorganic Chemistry. Electrodeposition. Molecular Structure and Properties of Gases. Physical Chemistry. Thermochemistry. Spectrochemistry. Pure Substances.

Mechanics. Sound. Mechanical Instruments. Fluid Mechanics. Engineering Mechanics. Mass and Scale. Capacity, Density, and Fluid Meters. Combustion Controls.

Organic and Fibrous Materials. Rubber. Textiles. Paper. Leather. Testing and Specifications. Polymer Structure. Plastics. Dental Research.

Metallurgy. Thermal Metallurgy. Chemical Metallurgy. Mechanical Metallurgy. Corrosion. Metal Physics.

Mineral Products. Engineering Ceramics. Glass. Refractories. Enameled Metals. Concreting Materials. Constitution and Microstructure.

Building Technology. Structural Engineering. Fire Protection. Air Conditioning, Heating, and Refrigeration. Floor, Roof, and Wall Coverings. Codes and Safety Standards. Heat Transfer.

Applied Mathematics. Numerical Analysis. Computation. Statistical Engineering. Mathematical Physics.

Data Processing Systems. SEAC Engineering Group. Components and Techniques. Digital Circuitry. Digital Systems. Analog Systems. Application Engineering.

• Office of Basic Instrumentation.

• Office of Weights and Measures.

BOULDER, COLORADO

Cryogenic Engineering. Cryogenic Equipment. Cryogenic Processes. Properties of Materials. Gas Liquefaction.

Radio Propagation Physics. Upper Atmosphere Research. Ionospheric Research. Regular Propagation Services. Sun-Earth Relationships. VHF Research. Ionospheric Communication Systems.

Radio Propagation Engineering. Data Reduction Instrumentation. Modulation Systems. Navigation Systems. Radio Noise. Tropospheric Measurements. Tropospheric Analysis. Radio Systems Application Engineering. Radio-Meteorology.

Radio Standards. High Frequency Electrical Standards. Radio Broadcast Service. High Frequency Impedance Standards. Electronic Calibration Center. Microwave Physics. Microwave Circuit Standards.

